Utility of international normative 20 m shuttle run values for identifying youth at increased cardiometabolic risk.

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Running Title: CRF and cardiometabolic risk

Abstract

The purpose of this study was to examine the ability of international normative centiles for the 20 m shuttle run test (20mSRT) to identify youth at increased cardiometabolic risk. This was a cross-sectional study involving 961 children aged 10–17 years (53% girls) from the United Kingdom. Receiver operating characteristic (ROC) curves determined the discriminatory ability of cardiorespiratory fitness percentiles for predicting increased cardiometabolic risk. ROC analysis demonstrated a significant but poor discriminatory accuracy of cardiorespiratory fitness in identifying low/high cardiometabolic risk in girls (AUC = 0.58, 95% CI: 0.54–0.63; *p* = 0.04), and in boys (AUC = 0.59, 95% CI: 0.54–0.63; *p* = 0.03). The cardiorespiratory fitness cut-off associated with high cardiometabolic risk was the 55th percentile (sensitivity = 33.3%; specificity = 84.5%) in girls and the 60th percentile (sensitivity = 42.9%; specificity = 73.6%) in boys. These 20mSRT percentile thresholds can be used to identify children and adolescents who may benefit from lifestyle intervention. Nonetheless, further work involving different populations and cardiometabolic risk scores comprising of different variables are needed to confirm our initial findings.

Key Words: Cardiorespiratory fitness; Fit; Adolescents; Cardiovascular Disease.

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Introduction

Cardiorespiratory fitness (CRF) is an important marker of cardiovascular health as it provides a measure of the capacity of both the cardiovascular and respiratory systems as well as an individual's ability to undertake prolonged and exhaustive exercise (Ruiz et al., 2016). In adults, CRF is strongly associated (independent of weight status and physical activity) with all-cause and cardiovascular mortality (Celis-Morales et al., 2017; Katzmarzyk, Church, Janssen, Ross, & Blair, 2005) and its importance for good health is well established (Blair et al., 1989). In youth, low CRF levels are associated with unhealthy cardiometabolic risk profiles, albeit weakly (Ekelund et al., 2007). Genetic factors influence the extent to which CRF can be developed (Bouchard, 2012), but recent findings have also demonstrated the mediating effects that moderate-vigorous physical activity (MVPA) (Carson, Tremblay, Chaput, & Chastin, 2016; Fairclough et al., 2017), total sedentary time (Carson et al., 2016) and specific sedentary patterns (Júdice et al., 2017) has upon measures of physical fitness and indicators of cardiometabolic risk. As such, providing opportunities for youth to increase their MVPA and CRF as well as limiting their sedentary behaviour seems prudent to ensure optimal health.

Evidence from tracking studies suggests that low CRF in youth is significantly linked to all-cause mortality in adulthood (Högström, Nordström, & Nordström, 2016; Sato, Kodama, Sugawara, Saito, & Sone, 2009). Since CRF tracks moderately well from youth to adulthood (Ortega et al., 2012; Twisk, Kemper, & Mechelen, 2002), there have been recent calls for the measurement and surveillance of CRF (Ruiz et al., 2016; Tomkinson et al., 2016) to be adopted by clinicians, nurses and

Physical Education practitioners who are tasked with identifying individuals at most need of lifestyle intervention.

Despite CRF being a common component in many youth fitness test batteries (Artero et al., 2012), CRF standards are rarely used by schools, clinicians or nurses to identify individuals with poor health profiles or to provide individualized feedback to students through school reports. One plausible explanation for this is the availability of national and international standards for BMI, a simplistic measure that can be easily and quickly captured by several individuals without the need for specialised training or understanding. Moreover, substantial evidence has found that obesity worsens nearly all of the major cardiometabolic risk factors (Alpert, Omran, Mehra, & Ardhanari, 2014; Bastien, Poirier, Lemieux, & Després, 2014). It is little wonder that monitoring weight status and the introduction of initiatives to manage obesity levels are often at the cornerstone of government strategies.

To encourage practitioners to include CRF assessments in youth cardiometabolic risk screening assessments, Tomkinson et al. (2016) recently proposed harmonised reference values by creating international normative centiles for the 20 m shuttle run test (20mSRT), generated on more than 1.1 million youth from 50 countries. The 20mSRT is a widely used field test of CRF, is able to test multiple individuals simultaneously, and demonstrates strong-to-very strong test-retest reliability and moderate-to-strong validity against gas-analysed peak oxygen uptake ($\dot{V}O_{2peak}$) (Tomkinson & Olds, 2008, 2007). To the best of our knowledge, no study has examined the predictive utility of the age- and sex-specific 20mSRT international normative centiles to identify individuals at increased cardiometabolic risk. Thus, the aim of this study was to examine the predictive ability of the recent 20mSRT international normative centiles to identify youth at increased cardiometabolic risk.

Methods

Participants and settings

Data were derived from cross-sectional studies evaluating the health status of Scottish and Welsh youth, with detailed methods described elsewhere (Brophy et al., 2012; Buchan & Baker, 2017). The study sample consisted of a Welsh cohort of Caucasian schoolchildren (n = 463 boys and 640 girls, 12.6±0.7 years of age) who were selectively recruited from 10 secondary schools during the 2009/10 school year. As we were concerned with the influence ethnicity would have upon cardiometabolic risk profiles (Winkleby et al., 1997), 85 non-Caucasian children were removed from the analysis. Despite being significantly younger, no differences in BMI or cardiometabolic risk were found between included and excluded participants. The Scottish cohort of Caucasian schoolchildren (n = 226 boys and 178 girls, 13.8±2.9 years of age) were recruited from three secondary schools and one primary school between 2010 and 2014.

Studies were approved by the University of the West of Scotland (Ref: REAG040909/BUCHAN/53) and by the Local NHS Research Ethics Committee-Dyfed Powys REC (Ref: 07/wmw01/12) in Wales. After excluding those participants who were absent from data collection or who withdrew blood sampling consent or who identified as being non-fasted, 961 youth (10–17 years of age, 53% girls) with complete cardiometabolic risk data were included. We decided to only include participants with complete cardiometabolic risk data to avoid imputation of biological variables and improve the stability of our results.

Measures

Stature was measured using a portable stadiometer (Seca Stadiometer, Seca Ltd, Birmingham, UK), body mass was measured without shoes to the nearest 0.1 kg using calibrated electronic weighing scales (Seca 880 and 770, Digital Scales, Seca Ltd, Birmingham, UK), with body mass index (BMI) subsequently derived. Participants were classified as overweight or a normal weight using BMI centiles relative to the age- and gender-specific UK 1990 BMI population reference data (Cole, Freeman, & Preece, 1995). Using the LMSgrowth software provided by the Child Growth Foundation (Pan & Cole, 2010), normal weight was defined as below the 85th centile and overweight at or above the 85th centile. LMSgrowth is a Microsoft Excel add-in designed for use with growth references based on the Lambda Mu Sigma (LMS) method which summarises data in terms of three smooth age-specific curves. The M and S curves correspond to the median and coefficient of variation of the variable of interest at each age whereas the L curve allows for the age dependent skewness in the distribution of the variable (McCarthy, Jarrett, & Crawley, 2001). The age-sex specific UK 1990 BMI LMS parameters provided with the LMS growth software allowed for the creation of exact percentile and z-score values for the subjects measured values.

Waist circumference (WC) (cm) was measured in a standing position midway between the lower rib and the anterior superior iliac spine following a normal expiration (Ledoux, Lambert, Reeder, & Després, 1997). WC-z scores were calculated relative to the UK 1988 age- and gender-specific reference data (McCarthy et al., 2001) available within the LMSgrowth software provided by the Child Growth Foundation (Pan & Cole, 2010).

Systolic and diastolic blood pressure (BP; mmHg) were measured using Omron M10-IT and Omron M6 automatic BP monitors (Omron Healthcare UK Ltd, Milton Keynes, UK). According to the manufacturers, the M10-IT device is equivalent to the clinically validated M6 device (Topouchian, El Assaad, Orobinskaia, El Feghali, & Asmar, 2006). The average of the second and third measures was used as the criterion value. CRF was measured using the 20mSRT with relative peak oxygen uptake ($\dot{V}O_{2peak}$, mL/kg/min) subsequently determined using a widely used prediction equation that has been validated on youth of similar age and ethnicity as those in this study:

$$\dot{V}O_{2peak}\ (\text{mL/kg/min}) = 31.025 + 3.238\ \text{speed} - 3.248\ \text{age} + 0.1536\ \text{speed} \times \text{age}$$

where speed is the running speed of the last completed stage (km/h) and age is age at last birthday (Leger, Mercier, Gadoury, & Lambert, 1988). Thereafter, sex- and age-specific CRF centiles were calculated for each participant using the LMSgrowth software provided by the Child Growth Foundation (Pan & Cole, 2010) using LMS parameters provided by the 4th author (Tomkinson et al., 2016).

Metabolic measures

Qualified phlebotomists collected venous blood samples between 8 am and 12 pm following an overnight fast and 30 min seated rest. In Scotland, blood samples were allowed to clot and then centrifuged at 4,000 rpm for 10 minutes. Samples were then analysed within 3 months using the following standard procedures. Triglycerides were measured by enzymatic methods (Randox, Antrim, UK) and a Camspec M107 spectrophotometer (Camspec, Leeds, UK). Concentration of high-density lipoprotein cholesterol (HDL-c) was determined after precipitation of very low density and low-density lipoproteins by the addition of phosphotungstic acid in the presence of magnesium ions. Glucose was measured using the glucose oxidase method (Randox, Antrim, UK) and analysed using a Camspec M107 spectrophotometer (Camspec, Leeds, UK).

In Wales, blood samples were allowed to clot and then centrifuged at 3,500 rpm for 10 min and analysed immediately. Triglycerides and glucose were measured by routine enzymatic techniques using the Vitros 950 System (Ortho-Clinical Diagnostics, Amersham, Bucks). The concentration of HDL-c was determined after precipitation of very low-density and low-density lipoproteins with dextran sulphate and magnesium chloride using the ILAB^{TM} 600 System (Instrumentation Laboratory Company, Lexington, MA, USA). Metabolic measurements were taken on a separate day to all other measurements.

Cardiometabolic risk score

A continuous cardiometabolic risk score was constructed using the following variables: triglycerides, WC, HDL-c, glucose and blood pressure. Triglycerides and HDL-c variables were normalized by the natural logarithm before constructing the cardiometabolic risk score. Each variable was standardized as follows: standardized value = (value – mean)/SD, separately for individual age-sex groups (e.g., 10-year-old boys). The standardized HDL-c value was multiplied by –1 to indicate higher risk with increasing value whereas the standardized values of systolic and diastolic blood pressure were averaged. Standardized scores were subsequently summed to construct a cardiometabolic risk score for each participant with a lower score being indicative of a healthier risk profile. This computed cardiometabolic risk score follows previous recommendations that support the inclusion of key metabolic syndrome components within continuous cardiometabolic risk scores (Eisenmann, 2008). Individuals with a cardiometabolic risk score +1 SD above the mean were identified as having increased cardiometabolic risk, similar to previous studies (Ramírez-Vélez et al., 2017; Sardinha et al., 2016).

Statistical analysis

Descriptive data are presented as mean (95% confidence intervals (CI)). Data were checked for normality with transformations performed where necessary. Triglycerides and HDL-c data were skewed and subsequently logarithmically transformed. Receiver operating characteristic (ROC) curve analyses were performed to examine the discriminatory ability of CRF percentiles to predict increased cardiometabolic risk quantified by the area under the curve (AUC). Although there were no formal sample size calculations undertaken prior to the collection of data, sample size estimates for studies involving diagnostic tests were undertaken in MedCalc 12.5 (MedCalc software, Mariakerkem Belgium). We used the lower limit of AUC values previously reported for boys and girls (Ruiz et al., 2015), with 80% power, 5% significance and a ratio of sample sizes of low/high cardiometabolic risk groups of 6. For boys, 105 participants (15 high cardiometabolic risk; 90 low cardiometabolic risk) were required and for girls, 497 participants (71 high cardiometabolic risk; 426 low cardiometabolic risk) were required. The most sensitive cut-off value for the detection of increased cardiometabolic risk was obtained from the Youden index with greater accuracy reflected in a higher score. ROC AUC values of ≥0.90 were considered excellent, 0.80–0.89 good, 0.70–0.79 fair, and <0.70 poor (Metz, 1978). Analyses were conducted for boys and girls separately. The AUCs for boys and girls were produced using MedCalc 12.5 (MedCalc software, Mariakerkem Belgium) whereas all other data were analysed using IBM SPSS Statistics 23 (IBM, Chicago, IL, USA) with $P < 0.05$ considered statistically significant.

Results

The descriptive characteristics of the study participants are displayed in Table 1. The prevalence of overweight was 32% in boys and 37% in girls ($p = 0.07$). ROC analysis demonstrated a significant but poor discriminatory accuracy of CRF in identifying low/high cardiometabolic risk in girls (AUC = 0.58, 95%CI: 0.54–0.63; $p = 0.04$), and in boys (AUC = 0.59, 95%CI: 0.54–0.63; p = 0.03) (Figure 1). The CRF cut-off associated with high cardiometabolic risk was the 55th percentile (sensitivity = 33.3; specificity = 84.5) in girls and the 60th percentile (sensitivity = 42.9; specificity = 73.6) in boys. The 60th percentile in boys aged 10–17 years ranged from 48.1 to 45 mL/kg/min (Table 2). The 55th percentile in girls aged 10–17 years ranged from 45.6 to 34.7 mL/kg/min (Table 2). By referring to an age and sex-specific reference table (Table 2), practitioners, clinicians and researchers can easily determine whether an individual has met the health-related CRF cut-point by referring to several common metrics.

Discussion

Findings from the ROC analysis demonstrated a significant but poor discriminatory accuracy of CRF for identifying the presence of cardiometabolic risk in youth. Our findings are in agreement with others involving European youth (Mesa et al., 2006;

Moreira et al., 2011; Ruiz et al., 2015) although it should be noted that the AUCs from this study were far from excellent and below most of those reported in the previously noted studies. It is possible that the relatively lower AUCs observed in this study are due to a different combination of risk factors used to construct the cardiometabolic risk scores. As noted elsewhere (Lang, Tremblay, Léger, Olds, & Tomkinson, 2016), different combinations of risk factors can yield different results, with individuals potentially classified as apparently healthy using one set of risk factors and unhealthy using another. It is also possible that between-study differences are due to age and sex differences between study cohorts. Further work may wish to consider the discriminatory accuracy of the international normative 20mSRT percentile values using multiple cardiometabolic risk profiles to confirm our findings.

Participants in this study were apparently healthy with no previously diagnosed cardiometabolic disorders which may have contributed to the lower than expected discriminatory ability of the international normative centiles. Since 46% of the participants had a CRF level above the 80^{th} percentile in relation to the international normative 20mSRT centiles, the reported AUCs could have been greater had there been more participants with poorer CRF levels and more variable health risk (e.g., including individuals diagnosed with cardiometabolic abnormalities) included. In healthy adults, it has been shown that high CRF provides better health protection than low CRF (Katzmarzyk, Church, & Blair, 2004; Lee, Artero, Sui, & Blair, 2010) but in youth, findings suggest that the association between CRF and CMR tends to improve in late adolescence (Ondrak, McMurray, Bangdiwala, & Harrell, 2007). Given the mean age of our cohort, it is also plausible that the reported AUCs may have been higher if a greater number of older adolescents with variable health risk were included.

From the optimal CRF cut-offs for both boys and girls, we observed relatively high specificity (74% and 85%) but low sensitivity (43% and 33%) respectively. This suggest that 73.6% and 84.5% of participants with low cardiometabolic risk were correctly identified whereas 42.9% and 33.3% of participants with high cardiometabolic risk were correctly identified. The low sensitivity of the CRF thresholds was surprising but is likely reflective of the age of the cohort and there being insufficient time for the younger participants to develop detrimental risk profiles (McMurray, 2013). Moreover, fatness is typically the most significant contributor to cardiometabolic risk in younger children (Jago et al., 2010; McMurray, 2013), and its these factors that likely explain the low sensitivity of these CRF thresholds. Finally, since there is not one measure of efficient standards, thresholds can be selected depending upon the desired result. In this study, the most sensitive cut-off value was determined based on the value that maximized the sum of both the sensitivity and specificity to reduce the likelihood of false negative and false positive misclassifications. If the desire was to ensure high sensitivity then it is likely that different CRF thresholds would have been produced but to the detriment of their specificity.

Encouragingly, the CRF percentile associated with increased cardiometabolic risk was broadly similar between sexes, falling in the upper end of the range for moderate CRF according to international standards for the 20mSRT (Tomkinson et al., 2016). This is an important finding which suggest that participants with low baseline CRF do not necessarily need to possess high CRF to improve risk profiles. Smaller improvements in CRF can also improve risk profiles which may be perceived as less daunting if participants currently fall below the 40th percentile for CRF according to the international standards for the 20mSRT. Whilst these findings are not surprising, to the best of our knowledge, this is the first study to examine the predictive utility of the recently proposed international normative 20mSRT centiles to identify individuals with increased cardiometabolic risk. This is an important first step in establishing whether these international normative centiles can identify individuals with increased cardiometabolic risk.

In youth, low CRF levels are known to be associated with increased cardiometabolic risk (Ekelund et al., 2007). Moreover, CRF levels in adolescence are known to track moderately well into adulthood (Ortega et al., 2012). It is important to note that CRF in youth can be improved on average by 8–9% in response to an appropriate 12-week training programme independent of sex, age and maturation (Armstrong & Barker, 2011). Improvements in CRF can also be achieved with shorter training programmes (Buchan et al., 2011; Lambrick, Westrupp, Kaufmann, Stoner, & Faulkner, 2016). This 8-9% improvement in CRF can be approximated to an increase of 20 centile points when using the recently proposed international normative 20mSRT centiles (Tomkinson et al., 2016) and could be used as an incentive for those wishing to improve their CRF. Nonetheless, the benefits of undertaking such training programmes should not encourage participants to become more sedentary given the emerging evidence and recommendations to reduce and break-up sedentary-time to enhance physical fitness (Júdice et al., 2017; Marques, Santos, Ekelund, & Sardinha, 2015). Particularly since the magnitude of improvement is likely to be greater in those that are sedentary with low baseline CRF (Armstrong & Barker, 2011).

Schools are often cited as a setting to encourage children to become more physically active and improve CRF (Ruiz et al., 2016), yet schools rarely assess CRF for the purposes of health promotion or disease prevention. One plausible reason for this could be the confusion surrounding the different approaches one can take to interpret 20mSRT performance which is a widely used measure of CRF in schools across the world (Lang et al., 2016; Tomkinson & Olds, 2008, 2007). For instance, the availability of least 10 available CRF criterion-referenced standards currently available for children and youth for practitioners to use (Lang, Tremblay, Ortega, Ruiz, & Tomkinson, 2017), all of which have been developed against different criterion health-related measures in different youth populations, creates confusion. Recently it has been proposed that CRF levels below 35 and 42 mL/kg/min for girls and boys respectively could be used in the interim to identify children and youth at risk of poor cardiovascular health (Ruiz et al., 2016). Moreover, the availability of an age- and sex-specific table provided by Ruiz et al. (2016) allows practitioners to easily determine whether youth achieve these health-related fitness standards. Nonetheless, there are several concerns related to these proposed thresholds that need to be considered.

Firstly, in their meta-analysis (Ruiz et al., 2016) the authors combine seven published criterion-referenced standards to determine that fitness levels below 35 and 42 mL/kg/min for boys and girls should raise a red flag. Yet these criterion-referenced standards were generated using varied methodologies comprising of different combinations of submaximal-effort or maximal-effort, different exercise modes, different $\dot{V}O_{2peak}$ prediction equations as well as field based or laboratory-based assessment protocols. Since the use of prediction equations to estimate $\dot{V}O_{2peak}$ may elicit some degree of error (Moreira et al., 2011), each method used may produce different results. Furthermore, evidence has shown that treadmill protocols can elicit a $\dot{V}O_{2peak}$ as much as 9% higher than that observed if using cycle ergometer protocols (Armstrong & Davies, 1981). Moreover, the use of age independent thresholds proposed by Ruiz and colleagues, given the known changes in relative $\dot{V}O_{2max}$ with age, particularly in girls (Armstrong & Welsman, 1994), may limit the ability of these thresholds to correctly identify individuals at most risk.

When comparing our proposed age-and sex-specific thresholds (Table 2) to that of Ruiz et al., (Ruiz et al., 2016), they fail to identify individuals (regardless of age or sex) as presenting with increased cardiometabolic risk. The disparity in thresholds is particularly evident for girls. For instance, during mid-adolescence (15 years) the CRF threshold is reduced by ~17% compared to only ~5% for boys. This is further exemplified when you examine the total reduction in thresholds from 10–17 years which shows a reduction of ~24% for girls and ~7% for boys. Thus, failing to account for changes in relative CRF with age, particularly in girls (Armstrong & Welsman, 1994), may lead to incorrectly identifying youth with increased cardiometabolic risk. Given the stigma of being incorrectly identified as demonstrating unfavourable cardiometabolic risk profiles and the demands upon limited resources this may have, it appears prudent in this cohort that a higher but more specific CRF threshold is used.

To assist practitioners with identifying individuals with low CRF and in most need of lifestyle intervention, we have devised a simple to use age-and sex-specific reference table (Table 2) which provides age-and sex-specific CRF thresholds in addition to the common metrics of speed (km/h), number of completed stages and number of completed laps. As many practitioners will have little time to convert 20mSRT performance into relative $\dot{V}O_{2peak}$ values, we hope that the reference table may be used to provide instantaneous feedback to individuals without the need for complex and time consuming mathematical computations. Thereafter, CRF values higher than the age- and sex- specific metric threshold can result in a green flag and described as healthy given the relatively high specificity values noted in this study. Nonetheless, CRF values below the metric threshold would not necessarily indicate increased cardiometabolic risk owing to the low sensitivity of the proposed thresholds.

This study is not without limitations. The cross-sectional design does not allow us to confer causality whilst the lack of objectively measured physical activity, sedentary behaviour and dietary habits, which are well-established confounders of several indicators measured, are acknowledged. We also acknowledge the limitations of using the z-score approach to calculate cardiometabolic risk. Whilst common within paediatric research, the z-score approach is based on the premise that each input variable is equally important in defining cardiometabolic risk, which may not be the case. Despite our large study sample, we recruited from two locations within the UK which limits the generalisability of our study findings. Moreover, over 46% of the sample had a CRF level above the 80th percentile in relation to the international normative 20mSRT centiles suggesting that participants were healthy and of good

CRF. It is likely that the reported AUCs noted in this study would have been greater had there been more participants with poorer CRF and risk profiles included. Finally, we did not consider psychosocial health outcomes when examining the predictive utility of the international normative 20mSRT percentile values in this study. A strength of this study was the use of a health-related, valid, and reliable field test to examine the use of recently published international normative 20mSRT centiles to establish their utility for identifying UK youth at increased cardiometabolic risk.

Conclusion

We propose optimal international normative 20mSRT percentile values that may distinguish UK youth with increased cardiometabolic risk. As this is the first study to investigate the utility of the international normative centiles, further work involving different populations with various constructed cardiometabolic risk scores are needed to confirm our findings. Moreover, further work should also consider capturing other measures of health and well-being such as cognition, academic achievement, behaviour as well as psychological health and quality of life. Finally, our reference table (Table 2) allows practitioners to provide instantaneous feedback to individuals in relation to their current CRF levels by expressing the age-and sex-specific CRF thresholds into several age-and sex-specific 20mSRT metrics. In doing so, we anticipate that this will negate the need for practitioners to undertake time consuming mathematical computations.

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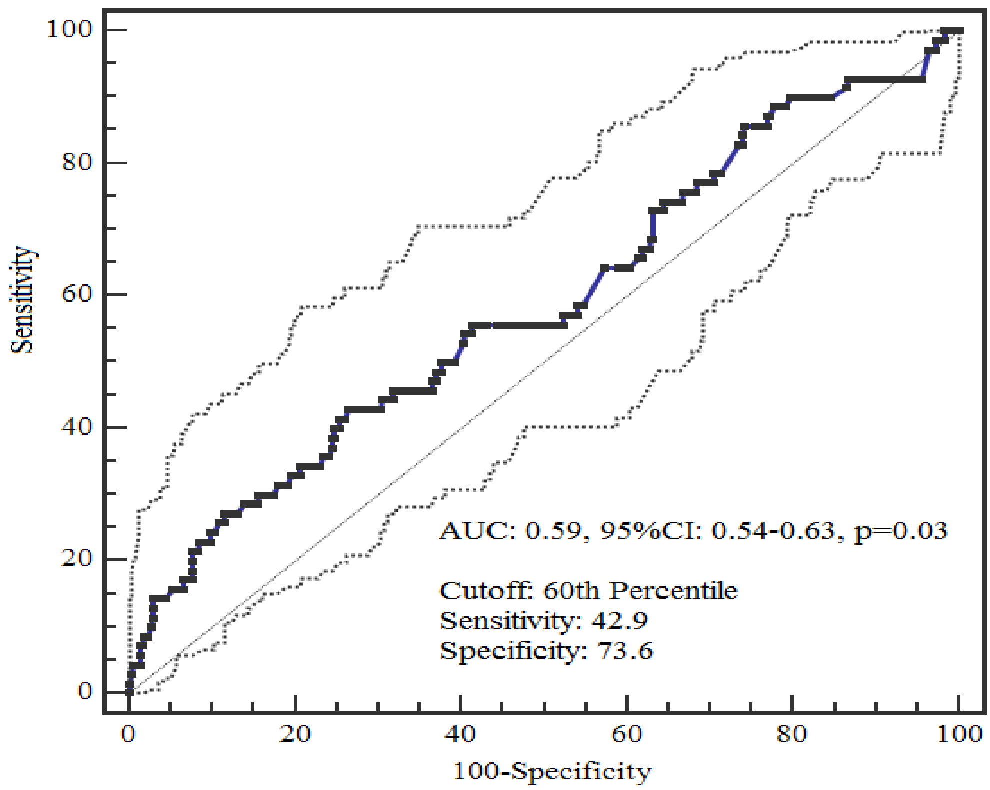
Boys



Girls

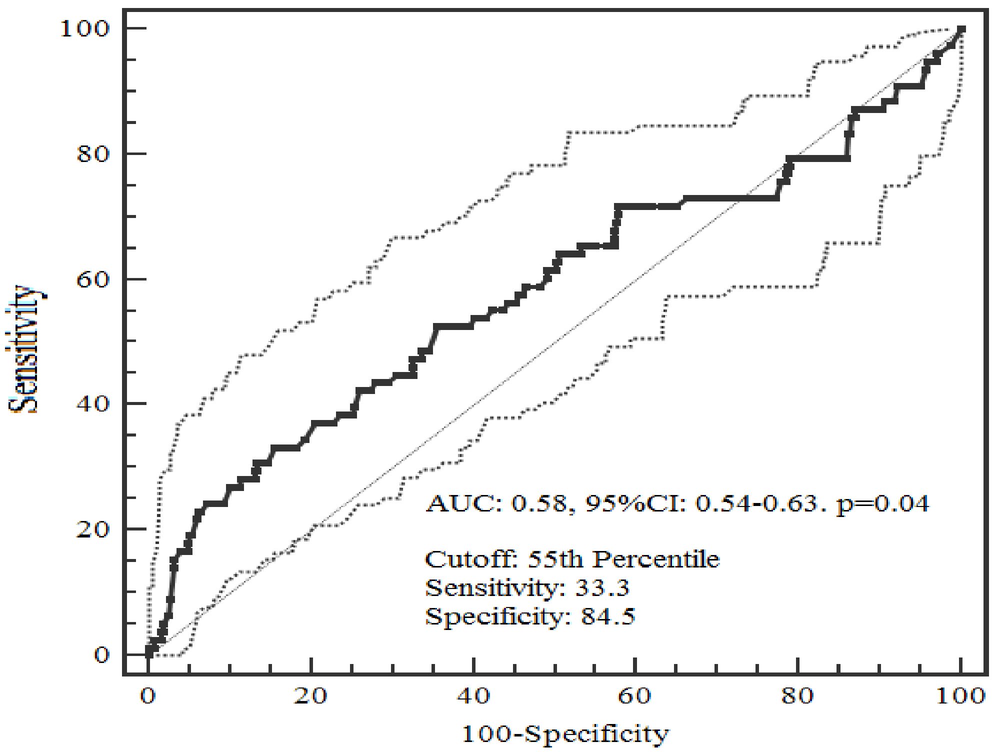


Figure 1. Receiver operating characteristic curve summarising the utility of CRF to identify low/high cardiometabolic risk scores in boys and girls. AUC indicates the area under the curve (95%CI). Note: Bold line represents the AUC; dashed lines represent the 95%CI.

Table 1. Descriptive characteristics of study participants with complete CRF and cardiometabolic risk data.

Variable	**Boys** n = 452 (47%)	**Girls** n = 509 (53%)
Age (years)	13.2 ± 2.1	13.0 ± 1.8
Height (cm)	157.9 ± 13.0	155.1 ± 10.0
Mass (kg)	50.7 ± 14.1	50.4 ± 12.6
WC-z	-0.03 ± 0.9	-0.04 ± 0.9
Systolic BP (mmHg)	117 ± 14	115 ± 12
Diastolic BP (mmHg)	66 ± 11	66 ± 10
Glucose (mmol/L)	5.0 ± 0.7	4.9 ± 0.7
Triglycerides (mmol/L)	0.8 ± 0.4	0.8 ± 0.5
HDL-c (mmol/L)	1.6 ± 0.5	1.6 ± 0.6
CRF (mL/kg/min)	50.2 ± 5.6	45.1 ± 5.9
Cardiometabolic risk z-score	−0.08 ± 2.9	-0.05 ± 2.8
High/Low cardiometabolic risk (n)	70/382	78/431

Values presented as mean ± SD unless otherwise stated. WC = waist circumference; BP = blood pressure; HDL-c = high-density lipoprotein cholesterol; CRF = cardiorespiratory fitness.

Table 2. Age- and sex-specific thresholds for healthy CRF for predicted $\dot{V}O_{2peak}$ (mL/kg/min) and three common 20mSRT metrics.

	Boys				Girls			
Age (years)	**$\dot{V}O_{2peak}$ (mL/kg/min)**	**Speed (km/h) at last completed stage**	**Number of completed stage/minute**	**Number of laps completed**	**$\dot{V}O_{2peak}$ (mL/kg/min)**	**Speed (km/h) at last completed stage**	**Number of completed stage/minute**	**Number of laps completed**
10	48.1	10.38	4.76	38	45.6	9.86	3.72	29
11	47.3	10.55	5.10	41	44.1	9.90	3.80	29
12	46.8	10.78	5.56	45	42.6	9.95	3.90	30
13	46.4	11.00	6.00	49	41.0	9.97	3.94	31
14	46.0	11.22	6.44	53	39.5	10.01	4.02	31
15	45.7	11.44	6.88	58	37.9	10.03	4.06	32
16	45.4	11.65	7.30	62	36.4	10.07	4.14	32
17	45.0	11.83	7.66	66	34.7	10.07	4.14	32